Barriers and enablers of climate adaptation in fisheries: Insights from Northeast US fishing communities

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1. Introduction

Climate change is increasingly impacting commercial fisheries globally, altering fish distributions and affecting stock productivity, as well as increasing storminess which can hinder fishers' abilities to go fishing and damage shoreside infrastructure (Barange et al., 2018; Sainsbury et al., 2018). Given these diverse impacts, successful adaptation is essential to enable fishing communities to minimise risks and benefit from potential opportunities (Barange et al., 2018; Ojea et al., 2020). Interest in climate adaptation in marine fisheries has grown in recent years, with assessments of adaptive capacity—the ability of people to prepare for, adjust and respond to change—gaining particular traction (Marshall et al., 2007; Marshall, 2010; Whitney et al., 2017; Cinner et al., 2018). While these assessments provide critical insights for climate adaptation planning, such approaches often posit having high adaptive capacity as a pre-requisite for 'successful' adaptation. However, many have questioned the extent to which higher adaptive capacity leads to correspondingly high levels of adaptation, cautioning that 'adaptive capacity will not necessarily translate into action' (O'Brien et al., 2006; Adger and Barnett, 2009; Mortreux, O'Neill and Barnett, 2020). Research increasingly indicates that circumstances and contexts can influence the extent to which adaptive capacity can be mobilised, and adaptation strategies and processes themselves can be interrupted, constrained and undermined by a multitude of factors (Moser and Ekstrom, 2010; Biesbroek et al., 2013; Eisenack et al., 2014; Islam et al., 2014; Islam et al., 2020). Influences that impede or facilitate adaptation can emerge across multiple levels of society—including individuals, groups and governments—as well as across spatial and temporal scales (Adger, Arnell and Tompkins, 2005; Moser and Ekstrom, 2010). Focusing on adaptive capacity alone may limit understanding of adaptation processes in fisheries systems, and therefore greater emphasis is needed on exploring how adaptation may be constrained or enhanced (Galappaththi et al., 2021).

In the broader climate adaptation literature, examining barriers and enablers of adaptation has formed an important component of improving understanding of why adaptation may (or may not) be successful and informing subsequent policy decisions (Moser and Ekstrom, 2010; Eisenack et al., 2014; Klein et al., 2014; Azhoni et al., 2018). Barriers and enablers can arise from physical, biological, social, economic, financial, governance and institutional realms (Biesbroek et al., 2013; Eisenack et al., 2014; Klein et al., 2014). Here, we define barriers as '*factors that make it harder to plan and implement adaptation actions*' (Klein et

al., 2014), and which are viewed as being surmountable or mutable, in contrast to limits, which are unsurpassable and absolute (Eisenack et al., 2014; Klein et al., 2014). Barriers can constrain the implementation of adaptation actions, make adaptation less effective or efficient, and result in missed opportunities or increased costs (Eisenack et al., 2014; Moser and Ekstrom, 2010). Opposite to barriers, there are also factors that enable or facilitate adaptation, which we term 'enablers' (termed 'opportunities' by the Intergovernmental Panel on Climate Change, Klein et al., 2014). These can '*make it easier to plan and implement adaptation actions, expand adaptation options, or provide ancillary co-benefits'* (Klein et al., 2014). In this sense, enablers provide conditions and opportunity for adaptive actions to occur (Klein et al. 2014; Azhoni et al., 2018)**.** Identifying barriers and enablers has recently been outlined as a key research priority for future fisheries adaptation research (Galappaththi et al., 2021).

Evidence is emerging that highlights several barriers and enablers of adaptation in fisheries systems. Frequently discussed barriers include the projected rapid rate of change and the uncertainty associated with future impacts (Holbrook and Johnson, 2014), inflexible and/or insufficient management systems (Holsman et al., 2019), resource and capacity constraints (Leith et al., 2014), and compromised resilience of overexploited fish stocks (Holbrook and Johnson, 2014, Pershing et al., 2015). Wider literature highlights the diversity of barriers that can exist and that may be unique to particular fisheries and localities, including outmigration and ageing populations of fishing communities (West and Hovelsrud, 2010), loss of infrastructure and facilities (West and Hovelsrud, 2010), impeded access to credit schemes (Islam et al., 2014; Alam et al., 2021), lack of technological equipment (Islam et al., 2014; Alam et al., 2021), constraints on access to shifting stocks (Dubik et al., 2019; Baudron et al., 2020), as well as psycho-social barriers such as low risk perceptions and low willingness to adapt (Nursey-Bray et al., 2012; McClenachan et al., 2020). Arguably, more research has focused on identifying barriers to adaptation compared to enabling conditions (Klein et al., 2014). However, examining enablers is equally important, as these conditions allow actors to successfully plan and implement adaptation actions, and may provide insights that studies of adaptation barriers alone may not fully capture (Klein et al., 2014). Enablers in fisheries contexts can include tools such as risk and vulnerability assessments (Klein et al., 2014; Gregg et al., 2016), information and knowledge exchange on adaptation options and experiences (Gregg et al., 2016; Shaffril et al., 2019), capacity building initiatives (Cinner et al., 2018; Shaffril et al., 2019), innovations in technology and infrastructure (Alam et al., 2021), and climate informed policy and management options (Holsman et al., 2019; Bell et al., 2020). Identifying both barriers and enablers together can therefore provide a more

holistic understanding into influences on adaptation and potentially greater insight for informing future decision making on adaptation in fisheries systems.

In addition to identifying adaptation barriers and enablers, examining where they arise within fisheries systems can provide further value for adaptation planning (Islam et al., 2014; Leith et al., 2014; Islam et al., 2020). Fisheries by their nature are complex socio-ecological systems, with social and ecological dimensions that continuously interact at individual, collective and governance scales (Ojea et al., 2020). Adaptation is also scale dependent, with adaptive processes, actions and outcomes occurring and being influenced by actors and interactions across multiple organisational, spatial and temporal scales (Adger et al., 2005; Klein et al., 2014; Ojea et al., 2020). Such complexity can impede adaptation planning and decision making because it often requires transdisciplinary and cross-scale solutions that may challenge traditional modes of fisheries management and governance (Leith et al., 2014). Adopting a socio-ecological lens to examine barriers and enablers of climate adaptation in fisheries is helpful for understanding future adaptation pathways and wider system resilience. Utilising frameworks that reduce the complexity of fisheries into more tractable key elements can aid adaptation planning by highlighting variables, processes and points of tension that can be critical to exploring, prioritising and pursuing adaptation options (Ostrom, 2009; Leith et al., 2014).

To contribute further to adaptation research in fisheries systems, this study adopts a socio-ecological lens applied to the New England region of the Northeast United States, a region whose commercial fisheries are facing a range of climate impacts. Using interviews conducted at four fishing communities, we ask 1) what barriers and enablers to climate change adaptation are people experiencing or perceiving? and 2) where do these emerge within the fishery socio-ecological system? We highlight the contextual nature of our findings to New England fishing communities and how adaptation relies on processes and actors at multiple scales. Additionally, we synthesize insights for climate adaptation planning that are broadly relevant to marine fisheries.

2. Methods

2.1 Case study: New England fisheries

The Northeast U.S. shelf is rapidly warming and home to a diverse range of fisheries that have significant economic, social and cultural value for New England fishing communities along its coastline (Pershing et al., 2015; Colburn et al., 2016). Climate impacts include sea

level rise and distribution and abundance shifts in target species, and many fishing communities are vulnerable due to their dependence on climate sensitive species (Colburn et al., 2016; Pinsky et al., 2020). Climate impacts on fishing communities can include changes in target species' abundance and productivity, and spatial distributional shifts away from traditional fishing grounds (Barange et al., 2018; Le Bris et al., 2018; Pinsky et al., 2020). Sea level rise can flood waterfront infrastructure important to fisheries, while changing sea conditions and extreme events can reduce opportunities to fish, damage fishing gear and infrastructure as well as pose direct risks to fishers' safety (Colburn et al., 2016; Sainsbury et al., 2018). Fishers are starting to adapt, including targeting new species, altering catch compositions, shifting to non-fishing livelihoods and, less commonly, travelling further to fish and switching to new ports (Young et al., 2018; Dubik et al., 2019; Pinsky et al., 2020; Papaioannou et al., 2021). However, for some stocks such as Gulf of Maine cod, failure of management systems to adapt to changing ecosystem conditions has reduced fishing opportunities (Pershing et al., 2015). While research has grown on examining the vulnerability and resilience of these fishing communities to climate change, knowledge gaps remain regarding future adaptation options and pathways.

Four fishing communities formed the focus of this research: New Bedford (Massachusetts), Point Judith (Rhode Island), Portland (Maine) and Stonington (Maine) (Fig. 1). Here, we view fishing communities as place-based, and use the Magnuson-Stevens Fishery Conservation and Management Act's definition of fishing community: *'a community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs'*. These communities are home to important fishing ports, which in 2019 collectively accounted for $593.5 million and 193.7 million pounds of fisheries landings (NOAA, 2020)—representing more than one-third of the value and volume of landings in all of New England. The four communities represent a range of fishing activities, and have undergone significant historical changes (e.g., regulatory, socio-economic, environmental), in addition to facing important climate-driven changes.

New Bedford is the U.S.'s most valuable fishing port and has a wide range of shoreside infrastructure and facilities, which not only benefit the commercial fleet operating from New Bedford but also those from further along the U.S. east coast. Vessels from New Bedford participate in a variety of fisheries, but approximately 85% of the port's landed value is derived from sea scallops. Point Judith is home to the largest fishing fleet in Rhode Island, including commercial and recreational fishing vessels. Commercial vessels participate in diverse fisheries, with longfin squid, summer flounder and sea scallop representing some of the main species landed in recent years. Located on the southwest Maine coastline in Casco

Bay, Portland is one of Maine's highest volume fishing ports, with landings of multiple species, including lobster, groundfish, and herring. Over the years fishers operating from Portland have struggled with access to and transformation of the working waterfront and a decline in shoreside facilities—issues not unique to this port (Donahue, 2014). Stonington—an island community in Penobscot Bay that is accessible by a single road bridge—is Maine's highest-value fishing port. Historically, landings to the port were diverse, but since the mid-2000s lobster has become the main fishery, representing 98% of the landed value and leading it to become known as Maine's lobster 'Capital' (Johnson et al., 2015).

<Insert Figure> Figure 1. New England (US) fishing communities examined. Boxes contain information on landed value, landed weight, key landed species to each community, and method of data collection. In Point Judith, one workshop was undertaken with nine participants.

2.2 Data collection

One workshop and 21 interviews were conducted with active fishers, fishing industry participants, and community members across the four communities (Fig.1, 31 participants total (one interview in New Bedford involved two participants)). 'Community members' are those living and/or working in the community and knowledgeable about fisheries, but not necessarily actively working within the fishing industry itself. Participants included fishers, seafood dealers and processors, municipal leaders, port authority staff and other key figures within the community. We examined perceptions beyond just active fishers to provide a more holistic view of adaptation processes affecting fisheries at a community scale and the different types of barriers and enablers that may be important to the fisheries system.

Interviews were conducted between February 2018 and October 2020. In Stonington, Portland and New Bedford, participants were selected using a snowball sampling approach that began with known industry and community contacts in each location, from whom input on potential interviewees was elicited. The process was repeated several times to identify potential interviewees that were recognised by multiple previous contacts, and who represented a diverse range of fishing community backgrounds and interests. Interviews were semi-structured, with questions focusing on several key themes but allowing further conversation where new topics arose. Key themes included changes people had experienced and/or expected to face (i.e., regulatory, market, environmental changes), perceived barriers and enablers to adaptation, and potential adaptation options. Interviews

lasted between 30 minutes to 1.5 hours and were undertaken at times and locations convenient for participants.

In Point Judith in January 2018, a workshop with 9 participants was conducted. Many fishers in Point Judith had participated in a series of interviews and workshops on similar topics (i.e. http://resilientfisheriesri.org/) during the months prior to our data collection effort. To minimise participant fatigue and build upon the prior workshop discussions and format, we designed a joint workshop to elicit input on the same themes that were addressed in our interviews. Modifications to interview questions were made to suit the workshop and group setting, but remained fixed on the same themes of research interest. Participants were identified based on their prior workshop participation and were selected to represent diverse fishing types and shoreside interests in Point Judith.

Conducting this workshop instead of interviews may have limited the depth of information provided by individuals, but given the recent large research efforts in the community prior to our project, we felt a workshop was the most suitable and efficient method to reduce further participant fatigue. Issues discussed at the workshop were broadly similar to those conducted during interviews, affirming that the different methodologies did not obscure the types and range of issues considered. Data collection across workshops and interviews stopped once we reached a point of hearing the same or similar themes across participants and communities, and novel themes did not frequently arise. Participants reflect a diversity of roles within fishing communities, and represent a range of fisheries and fleet segments (e.g. from small day-trip lobster boats and nearshore gillnetters to offshore groundfish trawlers and multi-day scalloping vessels), helping to capture a range of issues despite the small sample size from individual communities. For this reason, we emphasise the broader issues identified across communities within our results rather than disentangling specific community differences. Additionally, results were ‘sense checked’ and discussed through further workshops held with other members of the four communities as part of the wider project through which this research was conducted.

All participants provided verbal informed consent, and ethical approval was granted by University of Maine Institutional Review Board for the Protection of Human Subjects.

2.3 Analysis

Thematic analysis was undertaken on interview and workshop transcripts to identify barriers and enablers within and across the four communities. A semi-inductive approach was used,

coding and re-coding data before grouping into broader themes of barriers or enablers (Braun and Clarke, 2006). Such an approach allowed themes to emerge that were context-specific to the communities, as well as informed by relevant literature that has explored barriers and enablers to climate adaptation (e.g. Klein et al., 2014; Leith et al., 2014; Islam et al., 2014). All themes were discussed among authors to aid interpretation.

We also examined *where* barriers and enablers emerged within the fisheries socio-ecological system. We organised identified barriers and enablers in a socio-ecological systems framework outlined by Ostrom (2009), which was further developed into a fisheries climate adaptation context by Leith et al. (2014). This framework splits socio-ecological systems into five distinct 'sub-systems': 1) Resource Units, characteristics of fisheries resources that influence their adaptive capacity; 2) Users, including their traits, interactions and use of technology, information and knowledge; 3) Resource System, including physical (including infrastructure) and biological aspects and/or processes; 4) Governance System, including formal and informal organisations, institutions, relationships, networks and rules that govern action and affect adaptation; and 5) Social, Economic and Political Setting, encompassing external variables that influence adaptation within the fishery but are difficult to change from within the system itself (Leith et al., 2014). Further 'second-order' variables are included within the framework, which aided decisions of where to place barriers and enablers within the socio-ecological system (Leith et al., 2014).

3. Results

<Insert Figure> Figure 2. Barriers (a) and enablers (b) identified within the fishery socio-ecological system across all four communities. While barriers and enablers are likely to influence adaptation processes at multiple levels of the socio-ecological system, we show where they emerge in the system most prominently.

3.1 Barriers

A total of 13 barriers were identified, of which most were highlighted across all four communities (Table 1). These were mapped against four of the five sub-systems: Users, Resource System, Governance System and Social, Economic and Political Setting (Fig. 2). No barriers or enablers were identified for the 'Resource Units' subsystem.

<Insert Table> Table 1. Barriers identified from thematic analysis across the four communities (NB=New Bedford, PJ=Point Judith, PT=Portland, ST=Stonington).

3.1.1 'Users' subsystem

Four barriers centred on issues related to the 'Users' sub-system of the fishery: (1) business consolidation, (2) fisheries specialisation and dependency, (3) overcapitalisation and (4) shifting culture. Business consolidation was perceived to constrain flexibility and diversification by (1) limiting opportunities and access for independent fishers to acquire fishing permits, leading to uneven allocation of permits or quota across the wider fleet, and (2) reducing the amount and/or variety of shoreside services due to increasing vertical integration of businesses. Some respondents discussed how consolidation may also influence the power dynamics among fishers, with those landing high volumes or with more fishing permits perceived to hold greater power in decision-making than smaller independent operators. Fishing rights were also perceived to become expensive to lease or purchase, and independently owned shoreside services can be pushed out due to these increasing costs and their reduced competitiveness compared to larger businesses.

For most communities excluding New Bedford, the increasing specialisation in harvesting a limited set of species was seen as a barrier. Often perceived to result from historical changes in stocks and management regulations, specialisation can increase fishers' vulnerability to future shocks that affect their target species and reduce their ability to diversify due to specialised gear, vessels, techniques, and limited knowledge about operating in other fisheries. Linked to this barrier, and only discussed at Stonington, was the issue of overcapitalisation, whereby an individual or company has more debts than its assets are worth. In Stonington, new entrants to the lobster fishery have invested heavily in vessels and equipment due to motivations from the current lobster 'boom'. These investments may constrain future adaptation due to the high dependence they encourage, with high financial risk increasing fishers' vulnerability to future changes and making it harder to diversify if stocks decline and the high vessel prices limit potential buyers.

The final barrier identified was a perceived shifting culture among some Maine lobster fishers. Participants discussed a shift from viewing fishing as a lifestyle and centred on long-term planning, to more short-term mindsets with less of a conservation ethic to protect lobster stocks (e.g., V-notching tails of egg-bearing females and returning them to the ocean). This could be influenced by the recent lobster 'boom' in Maine, where many new fishers have not experienced historical stock variability and need to make money to offset their large investments; these fishers may place less value or focus on measures to protect lobster stocks for the future. Such shifting perceptions may impede adaptation because

295 people may be less inclined to ‘prepare for’ climate change and instead ‘react to’ impacts,
296 while a reduced conservation ethic may compromise the lobster stock’s longer-term
297 ecological resilience.
298
299 3.1.2 ‘*Resource System’ subsystem*
300
301 Two barriers emerged in the Resource System: (1) issues at the working waterfront and (2)
302 marketing and promotion of species. Working waterfront issues encapsulated a range of
303 problems that together were thought to affect access, impede opportunity and limit future
304 development of fisheries. These included a decline in amount and diversity of shoreside
305 infrastructure, which reduced the ability of fishers to catch different species and diversify into
306 alternative fisheries due to, for example, difficulties in finding processors for alternative
307 catches and sourcing new or specialised gear and supplies. Lack of parking was cited as an
308 issue due to growing demands on waterfront space, for example from tourism, that limited
309 places to park and unload near the dock as well as limiting further development of new
310 facilities or infrastructure to support the working waterfront. Through these multiple
311 influences, declines in shoreside infrastructure can affect long-term continuity of access for
312 fishing activities. In addition, a lack of processing facilities and ability to handle large
313 volumes of catch, such as lobster, meant that it was processed elsewhere (e.g. in Canada),
314 which limited local economic opportunities.
315
316 Successfully marketing and promoting species to enable fishers to take advantage of new or
317 emerging fishing opportunities was perceived as a challenge. Constraints included
318 limitations on market access due to geographic location or lack of a local market, which can
319 affect the logistical ability to distribute and supply markets with increased volumes of
320 species. The time and resources needed to establish new markets and/or supply chains, and
321 a lack of consumer demand for different fish species, further limited incentives to harvest
322 new or underutilised species. In Point Judith a particular issue was discussed whereby the
323 ability of fishers to sell products directly to consumers was hindered by State regulations (but
324 as of 2020, direct-to-consumer sales have been allowed as a result of regulatory changes in
325 response to the COVID-19 pandemic.)
326
327 *3.1.3 ‘Governance system’ subsystem*
328
329 Four barriers arose in the Governance System. The first centred on access to alternative
330 and/or emerging fisheries. Discussions centred on the high costs of permits and quota,
331 which affect who can gain access to species and makes diversification into new fisheries

financially challenging. Allocation of permits and quota across states, different sections of the fleet and between commercial and recreational fishers was also perceived to be problematic, with shifting abundances and distributions of stocks affecting the perceived 'fairness' of allocation arrangements. This issue mainly stems from the fact that such allocations are based on historical catches, with quota shares that are proportioned to states or individuals remaining fixed despite climate-driven changes in where species are found. Reallocation as species shift across traditional management boundaries (e.g., between states) is constrained by political and economic interests associated with the current arrangements. Linked to this topic was the issue that permits and quota to harvest commercial-scale volumes are often not available for species that are emerging in new areas, meaning that targeting these species is not economically worthwhile for fishers in areas where these species have not traditionally been present and harvested.

Another barrier related to perceptions that the science and information used in decision-making often led to inappropriate management decisions that affected people's ability to adapt. Issues centred on (1) the methods and models used to collect and interpret data; (2) lack of fishers' knowledge and information in scientific assessments; and (3) limited consideration of environmental, social and economic factors that may influence the fishery. These issues created perceptions that scientific advice was often 'wrong' and eroded trust in fishery management decisions and processes, particularly due to the feeling that what fishers experienced 'on the water' was different from what the science 'says'. The limited responsiveness of the management system was also perceived to be a problematic barrier. Fishers described decisions as lagging behind their current experiences and not keeping pace with the dynamic variability of the ecosystem. Others mentioned that the general decision-making process was slow, resulting in 'dragging out' decisions and making it difficult to plan ahead due to uncertainty over the final decisions. In other instances, the management system was criticised for being overly responsive and punitive, particularly when stocks were perceived by managers to be in decline and by fishers as undergoing a natural 'boom and bust' cycle.

A final governance barrier was associated with stakeholder input and power imbalances. Some participants felt that they had no voice in the decision-making process and that they were not listened to. Others felt that certain stakeholders or actors had greater influence in decisions, which led to decisions being made in their benefit rather than the benefit of all. These issues led to a general sense of distrust in the decision-making process, and meant decisions were not viewed as legitimate or fair due to perceived inequities in who could provide input into the process.

3.1.4 'Social, Economic and Political Setting' subsystem

Barriers to adaptation also arose from the Social, Economic and Political Setting. Changing composition and reliability of the industry's own and wider workforce was identified as one barrier. Issues centred on greying of the fleet, with current fishers aging and fewer new entrants that those retiring. Others discussed difficulties in finding dependable and qualified workers or crew due to changing community demographics and issues such as drug use. Drug use problems, particularly among younger adults, affected both the sourcing of crew and their reliability. Some ports, such as New Bedford, highlighted the value of immigrants to help fill gaps in the workforce when local labour availability was not sufficient, particularly for shoreside businesses and processing plants.

Another barrier related to views of non-fishing residents on development in the port and wider coast. For example, some interviewees felt people had 'Not In My Back Yard' (NIMBYism) views, which restricted the development of new fisheries infrastructure on the waterfront and the placement of aquaculture sites in coastal areas, both of which limit diversification options within and outside of fisheries. Another respondent discussed NIMBYism views in relation to the current push for development of wind farms offshore, with certain residents preferring these to be out at sea where they are less visible but may exert greater constraints on fishing grounds and fisheries.

The final barrier discussed by participants focused on financial feasibility of adaptation. While we placed this in the Social, Economic and Political Setting sub-system, this issue is cross-cutting across all sub-systems. Fishing is a financially challenging occupation, incurring high start-up costs, ongoing operating costs (e.g., fuel, vessel maintenance), variable incomes, and large financial risks. Shoreside investments in processing facilities or technologies to set up and improve marketability of species are also expensive. These costs mean that the ability to adapt is tightly dependent on an individual's or company's wealth, as well as the levels of financial risk they are prepared to take in investing in future plans.

3.2 Enablers

Seven enablers to adaptation were identified (Table 2), which were mapped to three of the subsystems: Users, Resource System, Governance System (Figure 2).

405 <Insert Table> Table 2. Enablers identified from thematic analysis across the four
406 communities (NB=New Bedford, PJ=Point Judith, PT=Portland, ST=Stonington).
407
408 *3.2.1 'Users' subsystem*
409
410 The adaptability and entrepreneurship of the industry was discussed as an enabler among
411 participants. Used to operating in a dynamic ecosystem, responding to fluctuating economic
412 markets and adjusting to regulatory change, fishing industry members have coped with
413 change in many forms and have some level of experience, skills and ability to equip them to
414 face future climate changes. However, some did note that this individual adaptability could
415 only take people so far, and other parts of the system—particularly regulations and costs
416 associated with access to different fisheries—also need to adapt.
417
418 Another enabler related to diversification options outside of the fishery. Some participants
419 discussed that they had additional incomes, education, skill sets and experiences that would
420 allow them (or people they knew) to diversify out of fishing if stocks decline or it became too
421 challenging, economically unviable or undesirable. Some described potential future options
422 for them or other fishery participants to diversify into other parts of the fisheries sector, such
423 as management or a fishing association, or to pursue jobs in aquaculture or other marine
424 sectors.
425
426 A final enabler centred on knowledge and learning. The role of knowledge of the fishery,
427 awareness of changes that are occurring, and the ability to learn new information and skills
428 were discussed by participants as being important to enable them to plan future business or
429 operational decisions, diversify across fisheries or adapt more broadly. Additionally, learning
430 from past experiences or observations allowed people to be more informed in their decision
431 making and equipped them with an ability to adapt to ongoing or anticipated changes.
432 Knowledge also was discussed as enabling people to advocate for change with decision
433 makers in management and governance contexts.
434
435 *3.2.2 'Resource system' subsystem*
436
437 Two enablers highlighted within the 'Resource System' subsystem were interlinked and
438 discussed in direct opposition to the 'issues at the working waterfront' barrier. The first
439 focused on the importance of communities recognising the value of the working waterfront
440 and having protections in place to prevent it from decline or non-fishery related
441 developments (such as condos and restaurants), which would allow continuity of access and

provide long-range planning horizons and security for the industry. Such protection was discussed in terms of historical (e.g. 'grandfathering') and current regulations protecting infrastructure, as well as having key stakeholders with 'foresight' to advocate and ensure such protections are in place. Tightly linked to this was another enabler: 'presence of shoreside services', which includes (but is not limited to) processors, netmakers and vessel maintenance services. The presence and range of shoreside services was perceived as vital to enable efficient on-the-water fishing operations; ease landing, processing, and marketing of catch; and facilitate diversification into other fisheries. New Bedford was described as particularly benefitting from the range of shoreside services it offered, which had helped it to become a fishing 'hub'. One participant discussed how future investment in shoreside services would also enable greater processing capacity to retain greater value-added benefits in their community, such as by processing American lobster locally rather than exporting it to Canada.

3.2.3 'Governance System' subsystem

The final two enablers discussed among participants arose in the 'Governance System'. Discussed in Maine only, participants highlighted the importance of fisher-led conservation efforts as a tool to enable future adaptation through increasing stock resilience. Measures advanced by harvesters in Maine's lobster fishery, including harvest size limitations and V-notching of egg-bearing females, were seen as critical to its historical and continued success. Some described such measures as acting as an 'insurance policy' to help them weather bad years.

Participants highlighted social networks as being important to assist them in times of change and enable sharing of knowledge, information and skills. Networks not only within social groups, such as fisher-fisher, but also among different groups and actors were discussed (e.g., fisher-consumer, fisher-decision maker). For example, some noted the value of sharing experiences of different fishing practices with other fishers. Others discussed the importance of having a community leader who was close to the fishery and helped advocate for the industry in community decisions. Leadership such as this can help to spur collective actions, set visions, build support and develop knowledge for longer-term adaptation planning, as well as enable quicker responses and recovery from environmental changes (Mason et al., 2021).

4. Discussion

We provide important new findings regarding some of the key barriers to and enablers of climate adaptation and highlight where they emerge within the fishery socio-ecological system. These insights are valuable for those working within the Northeast US, and provide considerations relevant to climate adaptation planning for fisheries in other countries and contexts. Concurrent with wider literature, we show a diversity of barriers and enablers, including but not limited to social, economic, financial, governance and institutional themes (Galappaththi et al., 2021; Islam et al., 2014; Klein et al., 2014; Leith et al., 2014). Such diversity highlights the complexities for adaptation within fisheries systems, both for those navigating the decisions of 'what' to do (e.g., fishers) and for those developing and implementing adaptation plans (e.g., municipal leaders). Some barriers are more commonly discussed within fisheries climate adaptation narratives, particularly those related to governance, such as responsiveness of management and access to emerging fisheries as species distributions shift (e.g., Hodgkinson, Hobday and Pinkard, 2014; Dubik et al., 2019; Holsman et al., 2019; Baudron et al., 2020; Ojea et al., 2020). Others have seen arguably less attention in the fisheries climate adaptation literature: access to the working waterfront, business consolidation issues and marketing or promotion of species. Many barriers and enablers were shared among the four communities, while others were community specific. Given that adaptation is a cross-scale issue, identifying commonalities can provide generalisable insights to guide adaptation planning at scales larger than individual communities, while in-depth explorations of communities is needed to inform localised approaches that address specific challenges or opportunities (West and Hovelsrud, 2010). As our results are based on a limited set of interviews across a small number of communities, we encourage further research to examine barriers and enablers within other fishing communities and fisheries contexts.

Results also indicate that potential interlinkages between barriers and enablers may influence adaptation processes and outcomes. Barriers could interact to further impede and constrain adaptation, introducing interdependencies that make them harder to overcome (Biesbroek et al., 2013; Eisenack et al., 2014; Islam et al., 2014; 2020). For example, in Stonington continued specialisation among lobster fishers has led many to become overcapitalised, which in turn encourages increased specialisation in this high-value fishery to ensure profitability to meet debt payments. Some have argued this, among other factors including changing demographics and rising home prices, has led to the Maine lobster fishery being a 'gilded trap', facing increasing precarity and vulnerability to future climate change (Steneck et al., 2011). The 'shifting cultures' barrier among some Maine lobster fishers may directly counteract the enabler 'fisher-led conservation efforts'. Decreases in compliance to 'v-notch' female lobsters because of conflicting views among some fishers

have been documented, raising potential issues over the continued use and benefit of this practice and threatening future sustainability of the fishery (Le Bris et al., 2018; Mazur and Johnson, 2020). However, interlinkages may also be reinforcing or complementary, such as between the enablers 'social networks' and 'knowledge and learning,' whereby formal and informal relationships can promote knowledge exchange and skill sharing between individuals and/or groups (Cinner et al., 2018). Adaptation planning therefore must also consider the dependencies and trade-offs between barriers and enablers that may arise through existing or potential interlinkages (Biesbroek et al., 2013; Eisenack et al., 2014; Klein et al., 2014). In doing so, recognition is needed that adaptation pathways vary depending on the individual or community, resulting in barriers and enablers, and hence interlinkages, being felt to different extents or in response to different climate drivers and exposures (Moser and Ekstrom, 2010; Eisenack et al., 2014; Klein et al., 2014; Ojea et al., 2020).

Many of the barriers and enablers identified herein are not necessarily 'new' and instead are connected to past changes experienced within the community or fishery. Many fisheries in New England have experienced significant declines, such as Gulf of Maine cod and Southern New England lobster, resulting in substantial social and economic impacts (Hunter et al., 2020; Le Bris et al., 2018; Pershing et al., 2015; Scyphers, Picou and Grabowski, 2019). Peoples' experiences of these events may have perpetuated perceived management and governance barriers we identified, such as negative perceptions of science and information, stakeholder input, and limited access to alternative fisheries (Dubik et al. 2019; Ebel et al., 2018; Hartley and Robertson, 2006; Scyphers, Picou and Grabowski, 2019). These past experiences may consequently erode trust in novel scientific projections, management decisions or management actors, thereby constraining fishery management options to respond to climate change as well as influencing stakeholder buy-in regarding approaches for wider adaptation planning (Dannevig and Hovelsrud, 2010; Ebel et al., 2018; Hartley and Robertson, 2006). Historical experiences of change can also influence peoples' future responses and abilities to adapt: notions of 'getting by', surviving difficult situations and adapting to a constantly changing environment can lead to perceptions of the industry being adaptable and entrepreneurial, enabling future adaptation and contributing to a wider sense of resilience (Johnson, Henry and Thompson, 2014; Korda, Gray and Stead, 2020 Chapt.5; Nursey-Bray et al., 2012). However, some have suggested such perceptions of high adaptability may affect fishers' receptiveness to prepare for climate change, which may be problematic given the rapid rate of warming and impacts occurring (Hodgkinson, Hobday and Pinkard, 2014; Maltby et al., 2021). Such examples illustrate the importance of historical changes in shaping perceived barriers and enablers, and their influence on future adaptation

processes and pathways more broadly (Adamson, Hannaford and Rohland, 2018; Biesbroek et al., 2013; Barnett et al., 2015). We argue further research is necessary to examine the drivers and potential influence of historical legacies on barriers and enablers of climate adaptation.

Identifying barriers and enablers provides the opportunity to guide efforts to support adaptation planning and implementation. Community specific barriers or enablers are best addressed through local level actions, which should aim to incorporate local experiences and understandings of change and needs in municipal investments, planning decisions, and fisheries management actions (West and Hovelsrud, 2010). Community organisations or fisheries associations can play a role in connecting individuals to share knowledge, information and ideas on future options, such as seen through the Rhode Island Fishing Industry's Resilient Fisheries project (Bell et al., 2020; http://resilientfisheriesri.org). Broader scale barriers will require interventions across multiple governance levels. For example, access to new or emerging species is impeded by current permitting and regulatory constraints, requiring significant changes at both state and federal levels of the fishery management system. Adjusting or reallocating quotas, changing fishing season timings, redefining stock areas and facilitating greater flexibility in permitting and licensing are some ways to reduce this barrier (Bell et al., 2020; Bryndum-Buchholz, Tittensor and Lotze, 2021; Gregg et al., 2016; Pinsky et al., 2020). Co-management approaches may help to address issues of agency and support knowledge exchange between stakeholders to build understanding and agreement around management issues (Bell et al., 2020).

Leveraging enablers also provides important opportunities to facilitate adaptation. Developing science-industry partnerships to enable information exchange and improve knowledge and learning on climate change impacts and options is one example, but operationalising them would also need to consider how to overcome potential difficulties of current perceptions of science and trust (Bell et al., 2020; Ebel et al., 2018). Promoting alternative or diversified livelihoods, identified by some participants as an enabler, offers different adaptation pathways for individuals, but such transitions depend on alternatives being viable; in practice, further barriers may exist to certain alternatives that were not highlighted through these interviews (Conejo-Watt et al., 2021). In addition to these practical steps for addressing particular barriers and enablers, opportunities also exist to consider these issues within fisheries adaptation planning more broadly. Outlining and developing potential adaptation pathways for different fisheries and fleet segments can allow the examination of what barriers or enablers will be most influential and under which adaptation circumstances (Werners et al., 2021). Scenario planning and future foresighting are also

590 valuable tools that enable greater interrogation of how barriers and enablers to adaptation
591 may affect realising preferred futures (Bell et al., 2020; Kelly et al., 2022). For example, the
592 current East Coast Climate Change Scenario Planning Initiative is helping to identify how to
593 address jurisdictional and governance issues in the face of climate change
594 (https://www.mafmc.org/climate-change-scenario-planning). While not immediate in enabling
595 responses in the face of rapid change, such exercises can help to build awareness and
596 progress business, industry and governance decisions under increasing uncertainty.
597
598 Using the Leith et al., 2014 framework allowed us to identify barriers and enablers emerging
599 throughout the fishery socio-ecological system and highlight the cross-scale nature of
600 influences on adaptation processes, and resilience more broadly, within fisheries. These
601 cross-scale issues will require interventions throughout, and we argue beyond, fishery socio-
602 ecological systems (Adger et al., 2005; Ojea et al., 2020; West and Hovelsrud, 2010;
603 Whitney et al., 2017). Interestingly our results did not find barriers and enablers within the
604 'resource units' sub-system, perhaps a reflection of our questioning and emphasis on social
605 considerations. Yet, this is important to consider given that most current efforts to develop
606 'climate resilient fisheries' and have 'climate-adaptive governance' (e.g. Bell et al., 2020;
607 Bryndum-Buchholz, Tittensor and Lotze, 2021) are ecologically-centric, emphasising
608 approaches and problems such as shifting stocks, declining catch potential, and altered
609 productivity. However, our findings show that adaptation processes in fisheries systems are
610 challenged not only by what is happening to the fish stock or being governed through 'at sea'
611 fishery management measures, but also by 'on land' social, ecological, and cultural
612 influences. Greater consideration is therefore needed to focus on other parts of the fisheries
613 socio-ecological system aside from the 'resource units'. It is imperative that effective
614 fisheries adaptation efforts consider issues on land, such as working waterfronts, an aging
615 workforce, rising financial costs, and marketing and promotion difficulties, which can shape
616 individual and community vulnerability and adaptive capacity, and ultimately influence
617 adaptation and resilience processes (Colburn et al., 2016; Steneck et al., 2011; West and
618 Hovelsrud, 2010). How adaptation varies throughout the fisheries supply chain is also
619 important; while one level of the supply chain may be resilient, another level which is not
620 could create widespread impacts. For example, during a marine heatwave in the Gulf of
621 Maine, the U.S. American lobster fishery experienced major disruptions as transportation
622 and processing capacity proved inadequate for the early harvest and high-volume landings
623 that were spurred by warm temperatures, ultimately leading to a price collapse (Mills et al.
624 2013). Supply chain issues caused by the COVID-19 pandemic have also affected many
625 fisheries (Stoll et al., 2021).
626

These challenges are further amplified by divergent governance frameworks designed for land and for sea. Currently, sector based (i.e., fisheries) climate impacts are primarily addressed by national policy, thus neglecting local and regional scale influences or potential mismatches between local planning (which typically addresses shoreside and coastal community needs) and sector-specific trajectories (Khan, Charles and Armitage, 2016; Singh et al., 2021a). Differences in responsibilities, priorities and needs between these approaches can result in opposing or contrasting directions in adaptation planning for fishing communities. Indeed, different stakeholders may have different views and framings of what constitutes 'effective adaptation,' such that addressing barriers or enablers may support adaptation at one scale or perspective but may create unintended consequences at other scales or to other stressors (Moser and Ekstrom, 2010; Singh et al., 2021b; West and Hovelsrud, 2010). Therefore, while efforts should continue to examine how sector-based governance and institutions can adapt to support stocks and fishers as they adapt to climate change, more holistic adaptation planning and implementation approaches that capture changes, conditions and people-place connections influencing adaptation both shoreside and at sea are needed (West and Hovelsrud, 2010). This could entail building greater connections between municipal and fisheries stakeholders to understand adaptation needs and goals; examining where adaptation plans at local, regional or national levels can be aligned or are complementary (and identifying potential areas of divergence or conflict); or identifying 'entry points' for policy integration between place-based and sector-based approaches (Khan, Charles and Armitage, 2016; Singh et al., 2021a; West and Hovelsrud, 2010). Additionally, most municipal adaptation plans focus on certain climate impacts (e.g. sea-level rise) in isolation of others, leading to plans that fail to address adaptation needs, leverage enablers, and overcome barriers in a holistic, integrated manner. Multi-issue comprehensive adaptation planning efforts are needed given the potential for complex cascading impacts as well as for synergies that could be realised in addressing barriers in ways that facilitate multiple objectives.

5. Conclusions

Through this research we demonstrate a range of barriers and enablers to climate adaptation across New England fishing communities, providing much needed insights into this understudied topic that are broadly relevant to adaptation planning efforts for climate resilient fisheries (Galappaththi et al., 2021). The identified barriers and enablers are diverse in nature, often interconnected and emerge throughout the complex fishery socio-ecological system, highlighting the need for adaptation approaches that can address scale-specific as

well as cross-scale issues. While climate adaptation planning and implementation is inherently future focused, we suggest that historical reflections and interrogations are important to examine how past legacies may shape future responses and the drivers of potential barriers and enablers. Finally, we argue that fisheries adaptation research and planning need to extend beyond considering changes at sea and additionally examine the broader cross-scale and land-sea connections that influence adaptation processes. Lessons from such integrated approaches will be critical for informing future adaptation planning and implementation measures to support climate resilient fisheries.

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Figures

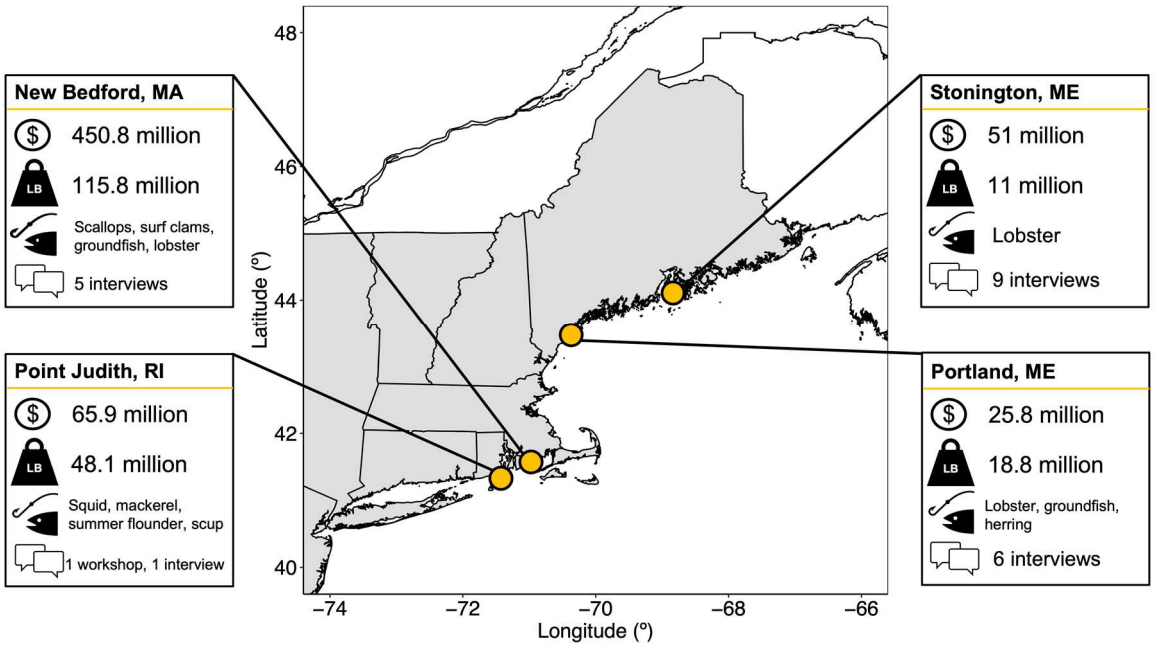
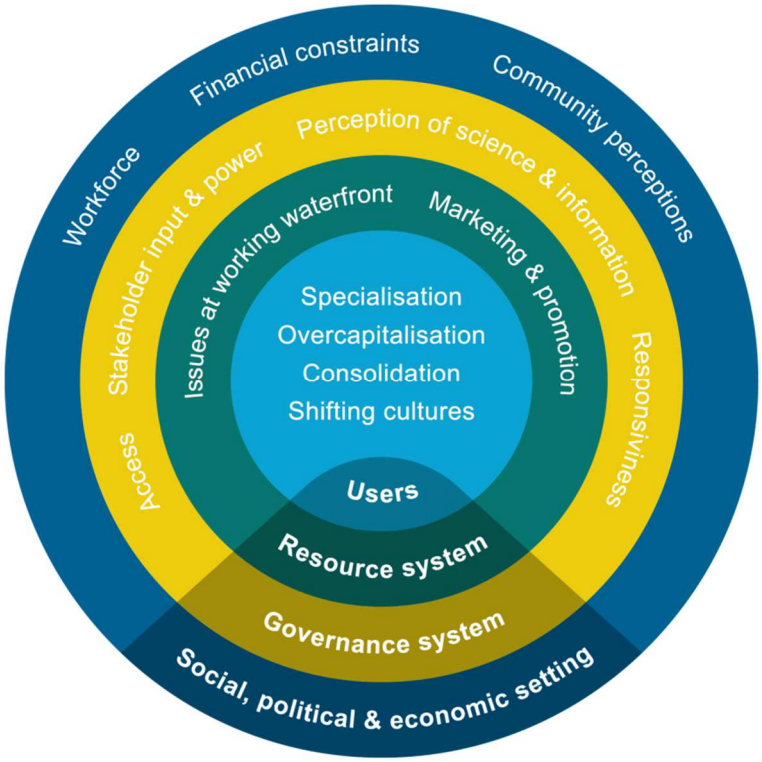


Figure 1. New England (US) fishing communities examined in this study. Each box contains information on landed value, landed weight, key landed species to each community, and method of data collection. In Point Judith, one workshop was undertaken with nine participants.

a)



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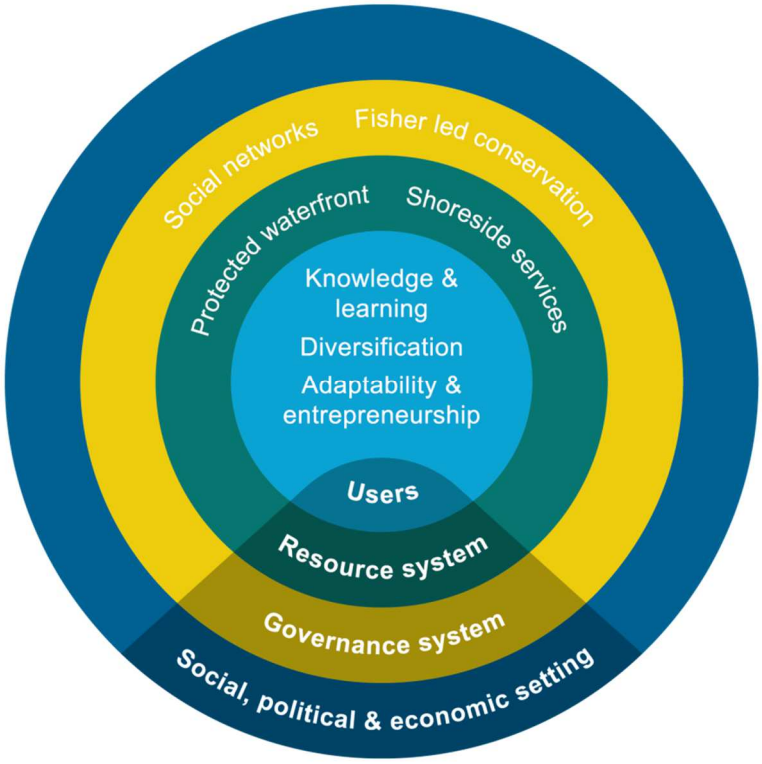

Figure 2. Barriers (a) and enablers (b) identified within the fishery socio-ecological system across all four communities. While barriers and enablers are likely to influence adaptation processes at multiple levels of the socio-ecological system, we show where they emerge in the system most prominently.

1049 Table 1. Barriers identified from thematic analysis across the four communities (NB=New
1050 Bedford, PJ=Point Judith, PT=Portland, ST=Stonington).

Sub-system	Barrier	Description	Communities which discussed this barrier
Users	Business consolidation	Increasing consolidation of vessels, fishing rights and on-shore services among fishing businesses.	All
Users	Specialisation & dependency	Certain fisheries have become increasingly specialised, resulting in high dependency of fishers and fishing communities on particular species, such as lobster.	ST, PT, PJ
Users	Overcapitalisation	Increasing specialisation, particularly in lobster, has resulted in large financial investments by fishers into their operations, resulting in overcapitalisation, whereby companies or individuals have more debt and equity than their assets are worth.	ST
Users	Shifting culture among fishers	A perceived shifting mindset among some younger Maine lobstermen who are focused less on long term planning and sustainability and instead on short term gains.	ST, PT
Resource system	Issues at the working waterfront	Loss of shoreside services and infrastructure at some ports constrains peoples' ability to diversify into other fisheries, while long-term continuity of the fishery and access is also threatened.	ST, PT, PJ
Resource system	Marketing and promotion of species	Issues include difficulty in accessing markets; a lack of established markets affecting the ability to sell new or emerging species; and a lack of consumer demand for new fish species hindering being able to sell them and disincentivising catching them. Food health and safety regulations can mean establishing new local direct markets with consumers is difficult.	All
Governance system	Access to alternative or emerging fisheries	Access issues centred on a number of themes: 1) high costs of permits; 2) lack of available permits at commercially viable volumes for many 'new' or emerging species; 3) allocation of permits is perceived to be unequal and problematic.	All
Governance system	Perceptions of science and information	Science and information used in management decisions are perceived to be inadequate due to: 1) neglect of other factors influencing the fishery, 2) not including fishers' knowledge, data or experiences, and 3) issues with the methods and models used to collect or interpret data and base decisions on.	All
Governance system	Responsiveness of management	Management decisions viewed as lagging in their responsiveness or being out of sync with	All

		fishers' experiences. This includes time lags between data collection and management decisions and slowness in action. In other instances, management can be overly responsive if a fishery is perceived to be declining or in crisis, when it may just be part of a natural cycle.	
Governance system	Stakeholder input and power imbalances	Issues discussed included: inputs into decision making processes were not listened to or acted upon; other actors or stakeholders had greater sway or power in influencing decision making; and there was unfairness in the balance of how fishers interests/needs were represented.	All
Social, economic and political setting	Workforce	Issues included: greying of the fleet, drug use among young workers, and issues surrounding recruitment and retention into the industry.	ST, NB, PJ
Social, economic and political setting	Wider community perceptions	NIMBYism perceptions and mindsets by those outside of fisheries on developments both onshore and offshore can hinder diversification options out of the fishery such as aquaculture, may lead to new pressures within the fishery (e.g., wind farms), or may hinder improvements or development to the working waterfront.	ST, PT, NB
Social, economic and political setting	Financial costs	Fishing and shoreside investments (e.g. facilities) are financially challenging and often involves high financial risk. This can mean diversifying fishing practices or into new fisheries is financially difficult or even unviable.	All

1076 Table 2. Enablers identified from thematic analysis across the four communities (NB=New
1077 Bedford, PJ=Point Judith, PT=Portland, ST=Stonington).
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Sub system	Enabler	Description	Communities which discussed this enabler
Users	Adaptability	Fishers and fishing businesses have always had to adjust and adapt to a dynamic marine ecosystem, meaning that they have some of the experience, skills and ability needed to overcome or buffer future challenges.	All
Users	Diversification out of the industry	Alternative incomes or other employment options outside of fishing provides diversification options. This could include aquaculture, other marine industries or investing for the future in 'something that's not just fishing'.	ST, PJ (only one)
Users	Knowledge and learning	Knowledge and learning have roles in both helping inform people's decision making, business ideas or fishing practices and also empowering people to advocate for change with decision makers.	ST, PT, NB
Resource system	Prioritising shoreside services	Shoreside infrastructure, facilities and services play a vital role in sustaining fisheries, enabling fishers to diversify into other fisheries and enabling access to other markets to process fish from elsewhere.	ST, PT, NB
Resource system	Protected working waterfront	Recognition of the value of the working waterfront, and protection of it from non-fishery related developments through historical or current regulations/city foresight, ensure there are facilities and infrastructure for the industry to use.	All
Governance system	Fishermen led conservation efforts	Actions taken by Maine lobstermen through collectively initiating and implementing conservation efforts to conserve stocks was perceived as crucial for ensuring a sustainable and resilient lobster fishery.	ST, PT
Governance system	Social networks	Social networks among different actors within or associated with fisheries systems can enable the exchange of information, skills and resources, and provide help and assistance in decision making or in times of change/difficulty.	All

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